# CHAPTER 9

# ILLUMINATION

## 9-1. Lighting maintenance.

Each lighting installation is designed to produce a specific level of illumination adequate for those working in the area. Adequate illumination should be maintained to reduce eyestrain, improve morale, increase safety, improve housekeeping, decrease fatigue, reduce headaches and increase production, all of which are directly reflected in lower operating cost. The maintenance of lighting systems is aimed at preserving the light producing capability at the original design level. Its necessity cannot be overemphasized. To prevent progressive deterioration of the system, prompt repair of any deficiency is essential. Since dirt accumulating and lamp aging are the two major factors which reduce the light output, it is necessary that lamps, fixtures and reflective areas be kept clean; defective lamps be replaced; and the voltage be held stable.

## 9-2. Fluorescent lighting.

There are three principal types of fluorescent fixtures; preheat, instant-start and rapid-start. All have practically the same physical dimensions but different internal construction. A preheat fixture has a ballast and starter which supplies nominal voltage to the lamp (fig 9-l). These are older style fixtures which cause the fluorescent tube to flicker before it lights. An instant-start fixture has a ballast which supplies a high voltage to the fluorescent tube to light it instantly. A rapid-start fixture has a ballast which requires a starting aid voltage between the full length of the lamp and the grounded metal surface of the fluorescent fixture. The type of circuit in which a particular lamp must be used is etched on the end of the lamp. For most applications, the 4-foot rapid-start lamp is the preferred lamp. Energy efficient lamps and electronic ballasts are also available. They can replace standard fluorescent lamps and save electricity by providing full-light output at reduced wattage and operating temperatures. Electronic ballasts can save up to 25 percent of the energy. The advantages of the electronic ballast besides energy saving, are lighter weight, less humming noise, dimmable and capable of operating up to four lamps at a time. The National Electrical Code Article 410-73 requires that all indoor fluorescent fixtures (except those with simple reactance ballasts) incorporate Class p ballasts with integral thermal protection. This requirement applies to all new installations and replacements. Older models with simple (single winding) reactance ballasts are an exception. The NEC Article 410-18(a) also requires that fluorescent fixtures as well as all other lighting fixtures and equipment with exposed conductive parts be grounded. Failure to properly ground the ballast and fixture combination could result in shock hazard. In addition to a shock hazard, failure to properly ground a fixture may result in frequent tube failures and trouble with starting for certain designs. For relamping or lighting retrofit it is important to assure existing ballast is in compliance with the new lamp. For example, when replacing a T-12 with a T-8 lamp the new ballast for the T-8 should be installed since the existing T-12 ballast is incompatible although the lamp bases are similar.

## 9-3. Incandescent lighting.

In an incandescent lamp, light is generated by heating the filament to incandescence. The hotter the filament, the more efficient it is in converting electricity to light. However, when the filament operates hotter, its life is shortened. Therefore the design of each lamp is a balance between efficiency and life. Incandescent lighting fixtures are designed for a particular lamp size and type. However, it is possible to use much higher wattage lamps in a fixture than the fixture or the circuit can adequately handle. The excessive heat of higher wattage lamps can damage the sockets, increase failure rates and overload the circuits. Personnel are cautioned to use only the lamp size (in watts) recommended for the fixture or smaller rather than a higher wattage lamp that may physically fit. Incandescent lamps come in a variety of voltage ratings. For most applications, the lamp voltage rating nearest the available line voltage should be selected. Under this condition, the lamp will produce its rated value of life, watts and light output. Energy efficient replacements are available for standard incandescent lamps. They provide better lamp efficiency with no loss in lamp life. Many incandescent lamps are available with life ratings in excess of ordinary general service lamps. Some have ratings of 5,000 hours or more and some even are guaranteed to burn for five years. Use of these lamps may be practical at locations where access is limited including high ceiling auditoriums, exit lights, stairwells, and marker lights on towers or fire alarm boxes. Use of an ordinary general service lamp whose voltage rating is higher than the circuit volt-

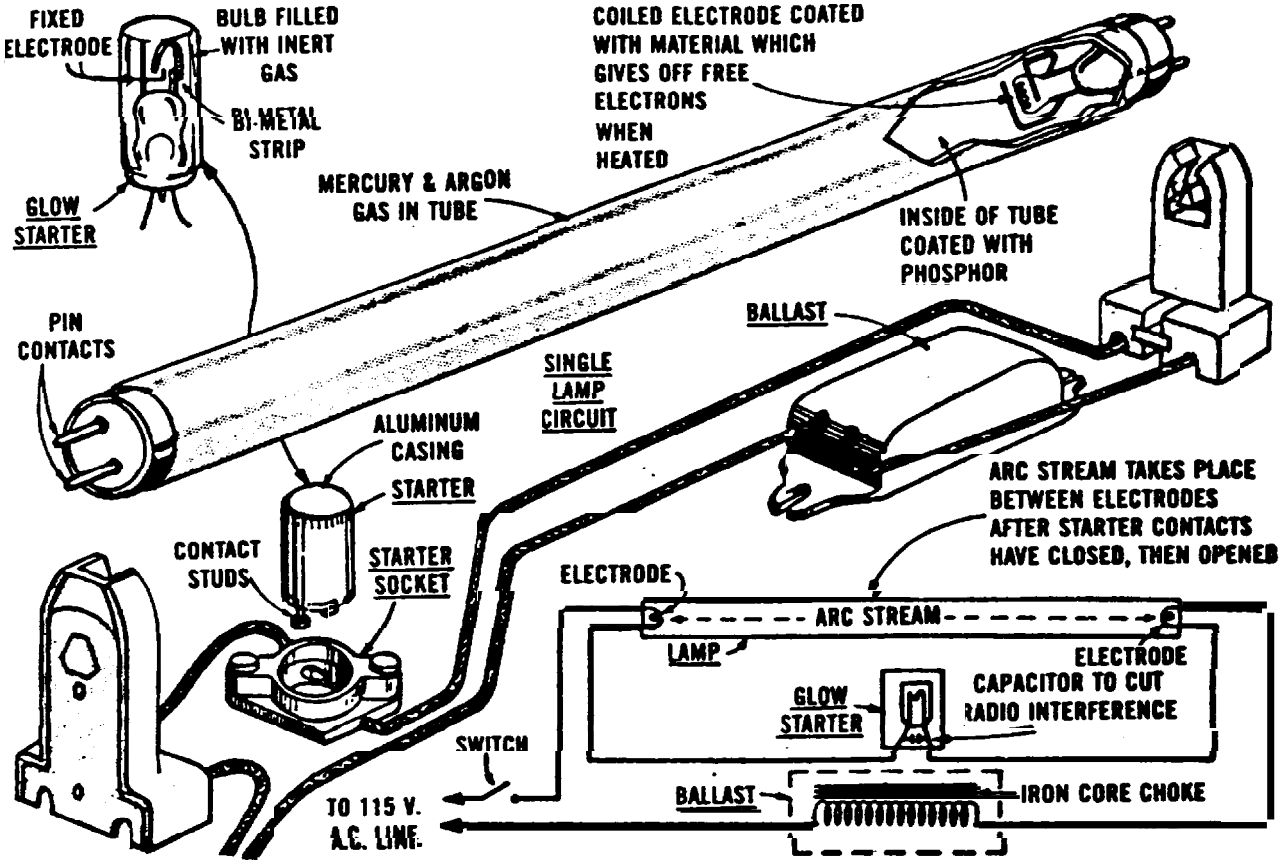


*Figure 9-1. Preheat fluorescent lamp and fixture components.*

age may be another alternative for inaccessible locations. By operating the lamp below its rated voltage, the life is increased but the light output is sacrificed.

## 9-4. High intensity discharge lighting (HID).

High intensity discharge lamps are those which have a gaseous discharge arc tube operating at pressures and current densities sufficient to generate desired quantities of visible radiation within their arcs alone. Every HID light source-mercury, metal halide, or high or low pressure sodium requires a ballast. Without a ballast, the lamp will not work; the arc will act as a short circuit and the lamp will destroy itself. Not only is a ballast necessary for lamp operation, but a properly matched ballast is essential to achieve rated life and performance with any HID lamp. Therefore, all ballasts should be designed to match the supply voltage with lamp requirements, to start the lamp and to control its performance throughout its life according to data published by the lamp manufacturer. Ballast designs differ widely between mercury, metal halide, HPS and LPS light sources and are therefore not interchangeable.

*a. Mercury lamps.* The maintained light output of mercury lamps is high because the electrodes operate at a relatively cool temperature resulting in less oxide contamination of the operating electrodes and the discharge gas. Long average life (24,000 hours or more) is a primary characteristic of most mercury lamps. While some models may have lamp bases the same size as incandescent lamps, standard mercury lamps must never be used to replace a burned out incandescent lamp (fig 9-2). However, there are self-ballasted mercury lamps which can be used as direct replacements for incandescent lamps. The installer should check which type is compatible with the fixture before turning on the power. An objectionable characteristic of mercury lamps is the time required to reignite (several minutes) after a momentary loss of power. It should be noted that this lamp can cause serious skin burn or eye inflammation from ultraviolet radiation if the outer envelope of the lamp is broken or punctured, and the arc tube continues to operate. Lamps allowed to operate in this way constitute both a fire and a personnel safety hazard and should be replaced promptly. There are certain lamps available that will automatically extinguish when the outer envelope is broken.

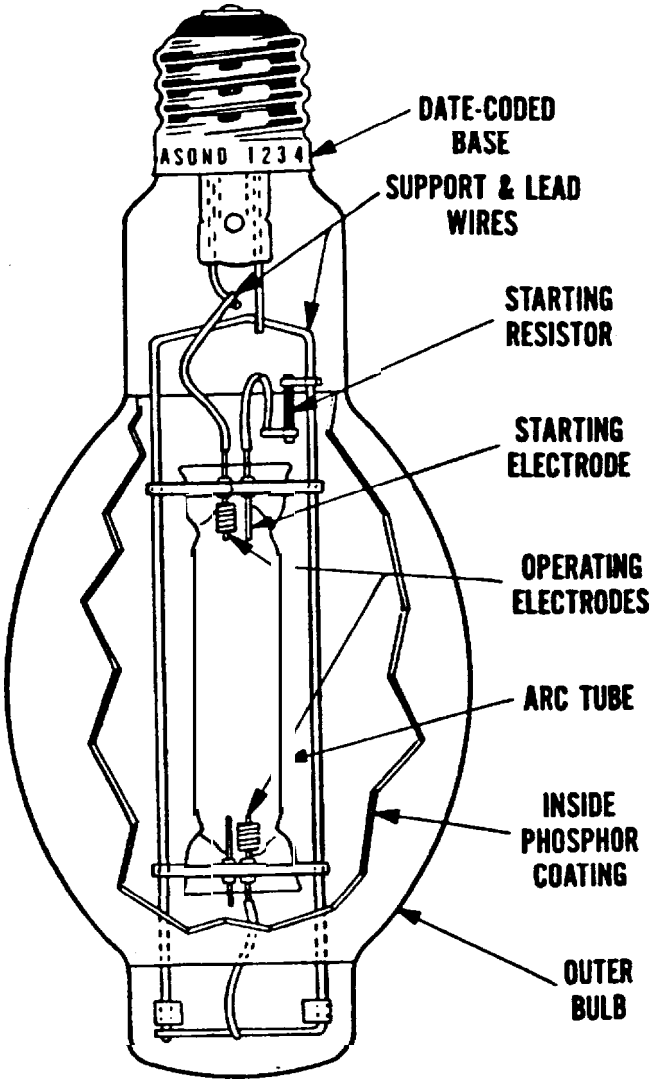


***Figure 9-2. Mercury lamp.***

*b. Metal halide lamps.* Metal halide lamps resemble mercury lamps in appearance and are used similarly. The color produced is better than mercury lamps and control of the light is easier. The initial efficiency is also better for wattages above 150W. Otherwise mercury lighting is more efficient. Disadvantages of metal halide lamps are a higher cost, and a shorter life expectancy than mercury lamps.

c. *High pressure sodium (HPS) lamps.* The HPS lamp package is similar to the mercury vapor lamp. Like most discharge lamps, the operating voltage is not compatible with supply voltage and a current limiting ballast must be used. The HPS ballast must compensate for both variations in line voltage and lamp voltage change due to ageing process in the tube. The mercury lamp operating voltage changes very little with life. With the HPS lamp, the ballast must compensate for changes in the lamp voltage as well as for changes in the line voltage. The operating voltage of an HPS lamp can change as much as 60 percent as it ages and the ballast operating characteristics throughout the life of the lamp is the key to good system performance. High pressure sodium. is more efficient than mercury or metal halide lamps.

*d. Low pressure sodium (LPS) lamps.* The LPS lamps are physically and electrically similar to fluo rescent lamps but without the phosphor coating. A ballast is required to start the LPS lamp. There is about a 10-minute warm-up period when the lamp is first turned on. LPS lamps are larger than mercury, metal halide and HPS lamps. The largest LPS lamp is 180 watts, 44 inches long and emits 33,000 lumens of yellow (monochromatic) light compared to a 400-watt HPS lamp 10 inches long which emits 50,000 lumens. There are about 1000 milligrams of sodium in the 180-watt LPS lamp compared to 6 milligrams of sodium in the 400-watt HPS lamp. Because of this, LPS lamps require special disposal precautions that do not apply to HPS lamps. Applications for LPS lamps are limited to roadways or floodlighting where color rendition is not important.

(1) *Installation.* A suitable ballast must be used. The ballast must be in compliance with Illuminating Engineer Society (IES) and/or ANSI specifications- If using power factor correction in a star connected multi-phase distribution, the power factor correcting capacitor should be connected between the line and neutral. A filter coil must be used if there is audio-frequency switching signals on the mains. The lamp should be installed within the indicated limits to avoid accumulation of sodium in the arc tube. Accumulation of sodium could reduce lamp life. Lamps of 90 watts or more must be set within 20 degrees of horizontal. Lamps of 55 watts or less may operate up to 20 degrees above horizontal.

(2) *Maintenance.* Do not allow the lamp to be scratched. Ensure that power is off before installing or removing the bulb. To avoid electric shock do not touch any metal parts of a broken bulb. A great degree of heat is produced by contact of the sodium with a small amount of water. Therefore the lamps must be stored or carried in their original container.

(3) *Disposal.* Let the lamp cool before removal. To avoid the danger of fire or broken glass, care must be taken in handling discarded lamps. No more than 20 lamps at one time should be broken into small pieces in a dry container of adequate size and in an open area. To avoid injury from flying glass, goggles should be worn. The broken pieces should be sprayed with water from a distance. When the chemical reaction has ceased the sodium is harmless and the broken glass should be disposed of as normal waste.

## 9-5. Cleaning.

The cleaning schedule should be coupled with relamping (spot/group schedule to minimize labor costs). The cost of cleaning versus replacement should be carefully evaluated. It is well-known that dirt absorbs and masks light. The progressive decrease of light caused by accumulating dirt renders periodic cleaning of lighting equipment-lamps, reflectors and lens--a necessity. The frequency of cleaning depends entirely upon local conditions. Fixtures in air-conditioned and air-filtered rooms may require cleaning only once a year. But in an atmosphere which is heavy with dust and fumes, cleaning every few weeks may be necessary. The cleaning intervals for a particular installation should be determined by light meter readings after the initial cleaning. When subsequent foot-candle readings have dropped 15-20 percent, the fixtures should be cleaned again. Readings should be made with the light meter at the working surface with the meter reader in the position of the operator or person using the working surface. Lighting equipment should be washed, not just wiped with a dry cloth. Washing reclaims five to ten percent more light then dry wiping and reduces the possibility of marring or scratching the reflecting surfaces of the fixtures. Glassware, reflectors and diffusing louvers that can be removed should be cleaned as follows:

*a. Immerse in the washing solution.* Do not immerse lamp base or electrical connections in the cleaning solution. Scrub with a soft brush or sponge. When incrustation is not removed by scrubbing, use No. 0 steel wool to remove dirt film.

*b. Rinse in warm clear water and dry with a clean cloth.* Walls, ceilings and surroundings are an important part of the overall illumination system since they redirect light to the working area. The most efficient lighting system is obtained when the fixtures are new and when the walls, ceilings, floors and furnishings of the room are clean and colored with a high reflectance color. A lighting maintenance program must therefore include cleaning and painting of the walls and ceilings in addition to the fixture cleaning schedule. Glassware, reflectors and diffusing louvers that cannot be removed should be cleaned as follows:

(1) *Wipe with a moist cloth or sponge.* When incrustation is not removed by sponging, use No. 0 steel wool to remove dirt film. Care should be taken to ensure that shreds of steel wool do not touch the pin contacts or get into the lamp socket.

(2) *Wipe off excess moisture with a clean cloth.* Clean fixture holders and stem hangers with a moist sponge or cloth and wipe dry. Enameled, chrome, aluminum or silver-plated reflecting surfaces that cannot be adequately cleaned and polished should be replaced.

## 9-6. Relamping.

The longer a lamp remains in service, the less light it produces. The different types of lamps-filament, fluorescent or high intensity discharge-depreciate at different rates. Since their life expectancy is also different, replacement intervals will vary. The two general relamping procedures are spot relamping and group relamping.

*a. Spot relamping.* Spot relamping is the replacement of individual lamps as they fail. Lamps that are blackened or discolored should also be replaced even if they are still burning because this discoloration indicates that the lamp will soon fail. Fluorescent lamps should be replaced as soon as they begin to flicker, or when the ends of the tube adjacent to the base blacken (fig 9-3).

*b. Group relamping.* Group relamping is most applicable to fluorescent lighting. When relamping, it is economical to wash the fixtures. It is also advantageous to inspect the sockets, hangers, reflectors and lens for broken glass, loose mountings, etc. Refer to the lamp manufacturer for recommended replacement intervals and relamping procedures. It should also be noted that replacement lamps must be of the same type, color, wattage and voltage as those being replaced. The following procedures apply:

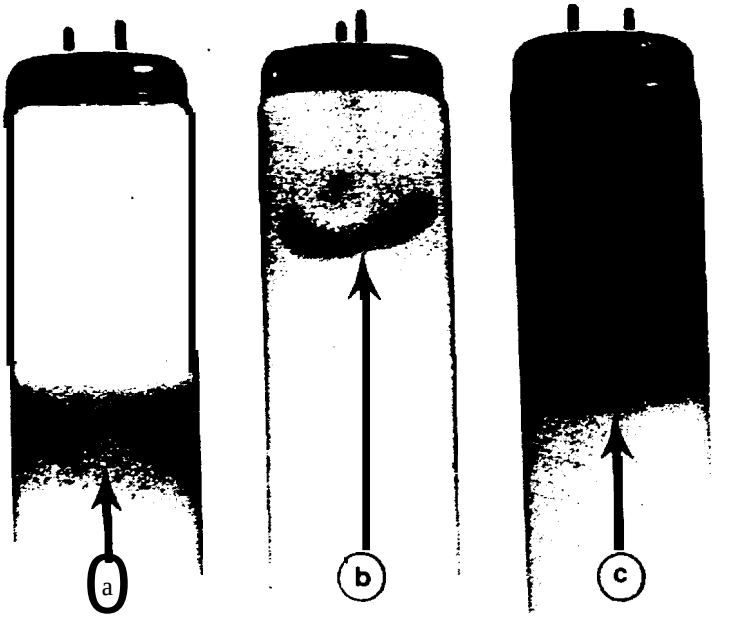


***Figure 9-3. Trouble-Shooting Fluorescent Lighting: a) Grey or brown bands 1"—2" from base are normal and do not affect useful life, b) Dark spots caused by condensed Mercury. Usually disappear after lamp warms up, c) Large blackened areas at ends mean lamp is at end of useful life.***

(1) Plan to replace all fluorescent lamps in a given area upon completion of 80 percent of rated burning life. Keep records of dates, costs, and other pertinent information as necessary to determine the realized savings.

(2) While the existing lamps are lighted, pick the best 20 percent of old lamps and save for replacement stock. Choose only the brightest and cleanest lamps for this purpose. Discard the remainder. Install new lamps in all sockets. Use the replacement stack to replace the first 20 percent of individual lamps as they burn out. When all of the replacement lamps have been used, make another complete replacement of lamps and repeat the process.

## 9-7. Lamp trouble-shooting.

Light sources operate most efficiently and economically at their rated voltages. Operation outside their normal operating range is undesirable. Both undervoltage and overvoltage conditions have detrimental effects on the life, efficiency, and economy of the light sources. These effects are as follows:

*a.* For fluorescent lamps, line voltage greater than the maximum ballast range will shorten lamp and ballast life. Line voltage less than the minimum ballast range will also shorten lamp life, reduce illumination and may cause uncertain starting. Frequent starting will shorten lamp life.

*b.* For incandescent lamps, line voltage greater than the maximum lamp range will increase the light output but will shorten the lamp life. Line voltage less than the minimum lamp range will extend lamp life but will reduce light output by approximately three percent for each one percent drop in voltage.

*c.* For HID lamps, line voltage greater than the maximum ballast range will shorten lamp and ballast life. Line voltage less than the minimum ballast range will reduce light output and may cause uncertain starting.

*d.* With the more common lamps and circuits, continuous flashing or blinking will destroy the starter, shorten lamp life and possibly damage the ballast. Whenever possible, replacement ballasts should be of the "P"-rated type that have internal temperature sensitive overload protection. This is not always possible as "P" ballasts may not operate satisfactorily in equipment that is otherwise satisfactory. Original type ballasts should be used if available. Replacement ballasts should be of the type having an overload circuit opening device. Other more common troubles encountered with lamp equipment, the probable causes and the suggested solutions are listed in table 9-1.

*Table 9-1. Lamp Trouble-Shooting Guide.*

| TROUBLE | PROBABLE CAUSE | REMEDY |
|---|---|---|
| **Fluorescent Lamp Equipment** | | |
| Lamp fails to start or flashes on and off . | Lamp pins not contacting. | Seat lamp firmly and correctly. |
| | Starter defective | Replace with tested starter |
| | Low line voltage | Match lamp rating to line voltage or increase line voltage |
| | Fault in circuit of luminaire | Check wiring and lamp holders. Check ballast |
| | Low temperature of surrounding air | Shield lamp from drafts. Enclose lamp to conserve heat. Maintain voltages within the rated voltage range of the lamp. Use thermal-type starters. |
| | Poor ground on rapid start ballast | Ground the fixture |
| | Lamp at end of life | Replace with tested lamp |
| Lamp flickers, swirls, or flutters. | Cold or too rapid starting | Allow a new lamp to operate a few hours for seasoning. Turn off a few moments - then turn on. Change lamps and, if flicker remains, replace starter. |
| End of map glow | Poor ballast | Check ballast |
| | Faulty starter | Replace starter |
| | Improper wiring or ground | Check wiring and ballast for ground |
| Lamp darkens early in life | Improper starting | Replace starter |
| | Low line voltage | Increase voltage |
| | Poor lampholder contact | Seat lamp firmly in lampholder. Check ballast and wiring |

*Table 9-1. Lamp Trouble-Shooting Guide-Continued.*

| TROUBLE | PROBABLE CAUSE | REMEDY |
|---|---|---|
| **Fluorescent Lamp Equipment** | | |
| Short lamp life | Low or high line voltage | Maintain branch circuit voltage within the range specified on ballasts |
| | Lamp turned on and off | Frequency of starting affects lamp life. Long periods of burning give long life. Short periods of burning reduce lamp life |
| Radio interference | Not installed properly | Auxiliary equipment should be enclosed in a steel channel. Wiring should be made up with tight connection; clamps and starters should be firmly installed in sockets and fixture grounded |
| | Line feedback | Install filter at radio |
| | Radiation direct from lamp | Locate radio antenna system at least 10 ft. from fixtures |
| Noise from ballast | Fluorescent equipment is not noiseless type | If unit is particularly noisy, replace ballast |

*Table 9-1. Lamp Trouble-Shooting --continued.*

| | | |
|---|---|---|
| Lamp fai1s to start | Lamp loose | Tighten in socket |
| | Low voltage | Increase lamp voltage by changing transformer tap |
| | Wiring fault | Check wiring. Tighten connections |
| | Low temperature | Lamps may not start when temperature is below 32° F |
| | Fluctuating voltage | Check line voltage. (Momentary dips of 10 percent, or more, often cause lights to go out). |
| Lamp frequently goes out | Lamp burned out | Replace |
| | Wiring fault | Tighten connections. Check wiring. Separate lighting circuits from heavy power circuits |
| Annoying stroboscopic effect | Cyclic flicker | Where there is a 3-phase supply, connect luminaries on alternate phases. On single phase, add incandescent luminaries to the system |

*Table 9-1. Lamp Trouble-Shooting Guide-Continued.*

| | | |
|---|---|---|
| Lamp not burning | Lamp loose | Tighten in socket |
| | Loose or broken connections | Secure terminals. Repair wiring |
| | Lamp burned out | Replace with new lamp |
| Lamp burns dimly | Low voltage | Match lamp rating to line voltage or increase line voltage |
| Short lamp life | High voltage | Match lamp rating to line voltage. Improve voltage regulation and avoid surges |
| | Lamp failure due to mechanical shock | Replace lamp. Be sure water does not drip on bulb. Use rough service lamps if required |
| | Incorrect lamp | Replace with lamp of size for which luminaire is rated |
| | Excessive vibration | Use vibration or rough service lamps |
| Lamp breakage | Water contacts bulb | Use enclosed vapor-tight luminaire if exposed to moisture |
| | Bulb touches luminaire | Use correct lamp size |